

ON THE STRUCTURE OF ANTICYCLONES AND CYCLONES IN THE STRATOSPHERE OVER EUROPE.

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510.5 (4)

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Lately, A. Schedler (1) correlated the observations of air pressure and temperature aloft, as obtained in the international series of flights, with the regions of rise and of fall in air pressure at the ground. It appeared that the front and rear sides as well as the center of regions of fall and of rise in pressure are characterized by transitory pressure and temperature changes differing in marked degree one from another. Since Schedler summed up the changes from one day to another he was able to derive approximate values of pressure and temperature distribution in cyclones and in anticyclones when lying side by side.

In this way he found a mean distribution of pressure and temperature along a cross-section from west to east through a region with both high pressure and low pressure; to be sure no claim can be made to great accuracy, and especially in amplitude, it is certainly too much reduced, since determination of means diminishes the extremes. However, it is plainly seen how over high pressure at the ground the pressure is high in the higher strata also, but the extreme shifts toward the west (backward inclination of the "axes" of cyclone and anticyclone); and it is plainly seen how above it (high pressure at the ground—Translator) the stratosphere lies high, while above high temperature at the ground the temperature remains high even up to the stratosphere, in which the extreme inclines somewhat forward (toward the east); however, over the warm stratum there lies cold stratospheric air. Exactly the opposite distribution is found with opposite sign (of departure).

This structure is essentially in complete agreement with the Dines' correlation factors relative to the free atmosphere.

A finding that appears interesting to me is made when Schedler's pressure and temperature values are presented together as has been done in the following figure. (Fig. 1.)

Here Schedler's figures (3 and 4) are placed one above the other; the values p_0 and t_0 indicate pressure and temperature at the surface of the earth (2); $p_{2.5}$ and $t_{2.5}$, the same at 2.5 km. elevation; p_7 and t_7 , the same at 7 km. elevation; p_h and t_h , the same under the limit of the stratosphere; while h and t represent respectively the height of the stratosphere and its temperature. No absolute values are given, merely the departures from mean values. The continuous curves represent values of pressure and of h respectively, the dotted curves represent temperature values; where a curve runs above its mean line the value is above the mean, etc. The curves are drawn over a high-pressure region and the two low pressure regions lying at the sides of the same. On the abscissas H indicates region of pressure rise and L indicates region of pressure fall; the annexed small letters indicate as follows: r for rear side, c for center, f for front side of H and L respectively.

There is noted in this figure a characteristic shifting of phase as between pressure and temperature curves which enters into many of the earlier conceptions of the structure of high depressions and anticyclones. Ficker (3) recently occupied himself with the matter when he explained the "compound" depression. In regard to these questions Schedler's results now appear to me to be quite interesting, even if, to be sure, merely

a scheme is obtained which still may require substantiation by direct coordination of pressure and temperature values at the several phases in the pressure formations in order to be relied upon fully. Yet, despite this uncertainty I believe that the scheme hits upon the reality of the structure the ground for such belief being the agreement with the Dines' factors and with the scheme of a high depression previously constructed by myself. (4)

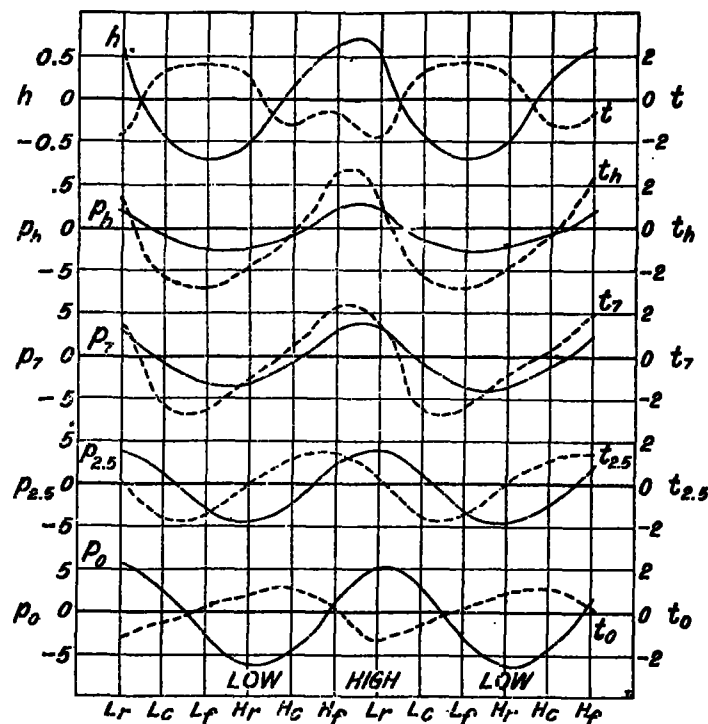


FIG. 1.—Temperature of the stratosphere, the height of its base, and pressures and temperatures at various levels in the troposphere.

For the understanding of the structure let us proceed from above—from the stratosphere. Here we see (in the two upper curves) high position of the stratosphere coincide with low temperature without any shifting of phase, and below, under the stratosphere, we see the pressure p_h with exactly the same course as h . Here the conditions are simple in the highest degree; when the cold stratospheric air lies high the pressure below it is high, and conversely. While over Europe at 10 to 12 km. elevation the west wind prevails we have really a pressure gradient toward north; the isobars run from west to east. They are at one place bent toward the South (lower pressure, p_h), next they are bent toward the North (higher pressure, p_h). Over the former place the stratosphere is warm, over the latter it is cold. If we descend into the uppermost tropospheric stratum we find there cold air in the low pressure region and warm air in the high pressure region (see note by translator), thus a contrast relative to the stratosphere; moreover the curve t_h already shows a slight shifting of phase to the West relative to p_h .

At 7 km. elevation the curve p_7 is slightly shifted in phase toward the east relative to the upper curves, at

2.5 km. elevation there is still more shift and at the ground the pressure extreme is found about one-eighth of the wave length farther to the east than the extreme of p_h . With downward advance the temperature curves undergo opposite shifting. The extremes lie farther and farther to the west. At 2.5 km. elevation the rear side of the anticyclone is warm, the front side is cold; at the ground almost the entire anticyclone is cold, but this conforms indeed to the temperature inversion near the surface of the earth on the fair mornings when flights were made, and which need not concern us too much. The distribution at 2.5 km. elevation much better represents the general conditions in the lower strata than does the distribution at the ground as here given. In the cyclone we are accustomed to finding the east side warm and the west side cold, in the anticyclone to finding the east side cold and the west side warm. The pressure and temperature structure presented in the figure conforms naturally to the barometric height equation. Each pressure value at the ground is given from the pressure aloft at the height h , p_h , and the temperature distribution prevailing below. Equal pressure values at the ground, p_0 , on the right and on the left sides of cyclones and anticyclone result thus in different manner from unequal pressure values p_h and different temperatures of the troposphere, as is detailed in my work on dynamic meteorology. So far the distribution of p and t presents no difficulties. Still it may be easily understood from this why the pressure at the ground, p_0 , (according to Dines) is not closely correlated with the variables aloft. The pressure p_0 assumes different distribution of p_h and t when it lies on the front side of a cyclone or anticyclone than when it lies on the rear side. At first the values p_0 and dp_0/dt together permit the expectation of a close correlation with the variables aloft; it would be desirable to determine these relations at some future time.

Of great interest at the present is the fact that the changes in the stratosphere have as a result relatively high and low-pressure regions, which are not asymmetrically formed as at the ground. The temperature above and below them is of the same phase as the pressure. There are thus in these upper regions no cold or warm front or rear sides. In the stratosphere the minimum is a whole is warm, the maximum as a whole is cold.

How is this difference relative to the pressure regions at the ground explained? The asymmetry in temperature near the surface of the earth arises from the fact that the air flows into the minimum from different latitudes. If the winds at the ground should blow parallel to the isobars then there would be no temperature asymmetry, they would circulate around regions of high and low pressure. Aloft the winds blow from west to east; the inward and outward curvatures of the isobars are followed by the stream lines; the northerly stream lines are warmer than the southerly ones so that curvature toward the south is filled by air generally warmer. We have reached the upper limit of the thermal structure of the atmosphere, the pressure distribution is primarily an effect of the polar whirl (gradient toward the Pole) and secondarily modified by changing temperature with streamline oscillation.

What Ficker calls the "primary" or upper depression is essentially different from the familiar lower one and it much simpler. The phenomenon of asymmetry first appears below the upper depression and develops slowly down to the ground. In the troposphere there gradually form, from indentation of the west-east isobars

by higher temperature at the south, closed isobars with the wind system belonging thereto—cold north winds and warm south winds. The low temperature of the north winds produces the shifting of the phases of the pressure curves to the east as the surface of the earth is approached.

The developed high cyclone or anticyclone became most easily understood when we proceeded from conditions in the stratosphere. An explanation as to origin in this way is not contemplated; there exists, on the contrary, no reason to assume that the phenomenon, has its point of origin aloft. If there is conceived at the earth's surface anywhere an inrush of cold air from the north, and if the same continues long, then the north wind and also the south wind completing the exchange of air will gradually invade the higher strata until even the stratosphere is drawn into the meridional shifting. Then there is obtained exactly the temperature distribution that is presented in the figure; cold under warm, warm under cold.

In their compilation of the international balloon ascents Wagner and Gold have calculated the mean values of temperature for the different regions of Europe, from which may readily be found the temperature gradients which are of importance in a horizontal shifting. The following table gives such temperature differences in the annual mean:

TABLE I.

	South minus North Europe (Wagner).	Milan, Pavia minus England, Hamburg, Paris, Nede (Gold).	Milan, Pavia minus Pavlovsk (Gold).	Milan, Pavia minus Berlin (Gold).	England minus Pavlovsk (Gold).
Earth.....	5.9	3.4	9.7	4.5	7.3
1 km.....	6.2	2.6	9.7	3.9	6.9
2 km.....	4.6	1.7	8.4	3.4	6.6
3 km.....	3.9	0.9	7.9	2.3	6.6
4 km.....	3.7	0.4	7.2	1.9	6.2
5 km.....	4.2	0.2	6.4	1.4	5.6
6 km.....	4.5	0.1	6.1	1.5	5.2
7 km.....	5.0	-1.2	4.1	0.4	4.2
8 km.....	3.9	-0.9	4.6	1.1	4.7
9 km.....	2.9	-1.5	2.9	0.5	4.1
10 km.....	1.5	-0.1	1.4	0.8	2.1
11 km.....	-0.5	-1.0	-1.5	-0.7	0.1
12 km.....	-2.0	-2.3	-4.6	-2.1	-1.2
13 km.....	-2.4	-2.5	-7.0	-2.8	-3.9
14 km.....	-2.2	-1.0	-5.8	-1.0	-4.2
15 km.....	-1.4	-2.1	-6.0	-0.8	-3.1
16 km.....	-0.2	-0.8	-6.1	1.3	-4.8

The series of values for these differences harmonize entirely with the scheme of the figure. Since on the front side of the depression and on the rear side of the anticyclone warm south wind is found, it would then be indeed very unnatural to assume that the upper cold (of the stratosphere—*Translator*) over these regions does not come from southern latitudes, thus unnatural to assume that the oscillations of the stratospheric temperature are not caused by shiftings of the stratosphere in horizontal direction. (5.)

Thereby the structure of the high cyclones and of the high anticyclones appears to be made considerably clearer. The high anticyclone forms from a south current, which is warm below and extends up to the stratosphere, where it brings cold; at the beginning (at the ground—*Translator*) the pressure is highest on its front side corresponding to the gradient of the south current.

In the middle strata through out-swelling toward the north of the stratosphere, which is colder toward the south, the high temperature of the south current coincides with high pressure; in the lower strata there arises on the east side of this high pressure a countercurrent from the north which shifts the temperature maximum to the west and the pressure maximum to the east, and thus brings about the phase difference between pressure and temperature distribution. On the other hand, the high cyclone arises from a north current, cold below and warm above; aloft the lowest pressure falls under the lowest position of the stratosphere. On its front side there develops in the lower levels a warm countercurrent which shifts the pressure minimum toward the east and the temperature minimum toward the west. The "tie" between upper and lower pressure formations is fully accounted for from this. It is a matter of only one depression which has phase shiftings, locally possibly different, but it is not a matter of two depressions, an upper and a lower, as Ficker supposed. The high pressure above is characterized by the fact that it is as a whole cold, the low pressure by the fact that it is as a whole warm. The thermal explanation of the phenomena is practicable when it is borne in mind that for dynamic reasons the isobars run from west to east, that thus at the north there lies really a lesser mass above the given high level than there lies at the south. In this way the south current brings rise in pressure aloft, while the north current brings fall in pressure.

The fact that over a region with 1,000 to 2,000 kilometers radius, and up to several kilometers elevation, the air can be warm and can meanwhile move downward, the fact of the stationary anticyclone, warm below, may be explained, so far as I see, not otherwise than by a south current in the substratosphere, whose cold air sinks at the north in warmer regions and meanwhile forces down the lower, dynamically heated air. This anticyclone has thus certain similarity to a waterfall, the center of gravity of the entire mass descends despite the descent of warm

air. We have a circulation in which the energy is furnished by the cold substratospheric air of the Tropics and the sub-Tropics.

The terms "north" and "south" are used here representatively. Taken exactly it is a matter of the position of the stratosphere relative to the season; in Europe, as is evident from the above table, the oceanic west (England) stands in similar contrast to continental Russia as normally the south stands to the north.

In the building of high cyclone and anticyclone from a lower formation the cold mass of air forcing its way at the ground is evidently the bearer of high pressure until the higher air strata of the stratosphere are drawn into the northerly and southerly winds. With this, then, the highest pressure over the western limit of the cold air goes out over the warm air following (in the circulation—*Translator*), the lowest pressure removes from the warm southerly current westward into the mass that is cold below. The cold wave precedes the high pressure in the advance toward the east. We are not able to judge as to what extent the inward and outward curvatures of the stratosphere change independently.

BIBLIOGRAPHY.

- (1) Die Beziehungen zwischen Druck und Temperatur in der freien Atmosphäre. *Beitr. z. Phys. d. fr. Atm.*, Bd. 9, Heft. 4.
- (2) I owe the values t_0 to courteous communication from the author.
- (3) *Meteorol. Zeitschr.* 1921, S. 65.
- (4) *Sitzungsber. d. Akad. Wiss.*, Wien, Bd. 119, Abt. 2 a, S. 697, 1910.
- (5) Compare my paper in *Meteorol. Zeitschr.* 1913, S. 434.

TRANSLATOR'S NOTE.—The sentence "Gehen wir zur Obersten Troposphären schicht herab, p. 297, line 15, is rendered with interchange of the words "warme" and "kalte" since this appears to be in agreement with the curves p_h and t_h .

ORIGINAL TEXT.—Über den Aufbau hoher Antizyklonen und Zyklonen in Europa. Felix M. Exner. *Meteorologische Zeitschrift*, 1921, Heft 10, Oktober.—W. W. R.

THE TORONTO SYMPOSIUM ON BAROMETRIC REDUCTIONS.

551.54 (682.2) (71) (73)

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A suggestion made at the Chicago meeting of the American Meteorological Society in 1920 developed, at Toronto, into a satisfactory symposium on the reduction of barometric pressure in the United States and Canada. This symposium should not be regarded as a culmination of effort, but rather as a significant step toward a goal, the road to which is beset with many pitfalls and obstacles. But there is little doubt, it is believed, that this symposium does signify much for the future of American barometry. For 20 years, the United States, Canada, and the West Indies have used the system of barometry devised by Bigelow. This system was, without question, a thorough and capable treatment of one of the knottiest problems of practical meteorology; but it was not exhaustive—even in the mind of Bigelow the work was not finished—revisions and reexaminations of the gradients, methods, and errors, should follow after a few years of taking homogeneous observations. But these 20 years have passed. Those most familiar with the reductions are well aware of the fact that they are not the best; at the same time, improvement of Bigelow's treatment is regarded as most difficult. The Toronto symposium was born of this consciousness of the difficulties of reduction. Whether this symposium will result

finally in an improved system of reductions depends upon how thoroughly and searchingly the problem is studied, and how practical and workable are the suggestions offered by investigators.

In order that those who did not have the opportunity of attending the Toronto meeting may be informed of this interesting session, it is believed that a brief résumé of the several papers, in the order of their presentation, may be of value.

The nature of the problem from the practical standpoint was stated in a short communication from Prof. C. F. Marvin, Chief of the United States Weather Bureau. He said, in part:

It is well known that, strictly speaking, a reduction to sea-level of continental observations is wholly a visionary and hypothetical thing, since to effect the reduction we must necessarily assume that an atmosphere exists below the station whose observations are to be reduced. We assign to this atmosphere a given temperature and moisture content, density, etc., and our reduction depends upon these assumptions. Since the intervening atmosphere has no existence our assumptions are necessarily fictions, and the final result of the so-called reduction to sea-level has in reality no meaning.

He then explained how, by so treating the temperature argument and the other assumptions that they will satisfy the requirements for smooth isobars on the daily